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WRIST RHYTHM DURING WRIST JOINT MOTION EVALUATED BY DYNAMIC RADIOGRAPHY

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ABSTRACT

We hypothesized that wrist joint motion involves a "wrist rhythm" similar to the scapulohumeral rhythm. Therefore, we used a flat-panel detector to evaluate the ratio of radiolunate and capitolunate joint motions during wrist joint motion by dynamic radiography. The subjects were 20 healthy men. Dynamic imaging of the wrist joint was performed during active exercise for a total of ten seconds. In this study, we defined the radiocarpal (RL angle) and midcarpal joint angle (CL angle) as the wrist joint angle in the obtained images and measured the variation of these angles. The average curve was plotted and regression lines calculated from the average curve. The ratio was calculated from the slopes of the regression lines of the RL CL angles. These findings indicated that the ratio of the RL and CL angle motions was approximately 1:4 during palmar flexion and approximately 2:1 during dorsiflexion.

Keywords: Wrist Rhythm; Radiocarpal Joint; Midcarpal Joint; Dynamic Radiography.

INTRODUCTION

In wrist joint movements, palmar flexion has been reported to predominantly involve the midcarpal joint and dorsiflexion to predominantly involve the radiocarpal joint.[1–3] However, these reports only described the "contribution ratio" of each joint movement at the maximum palmar flexion and maximum dorsiflexion positions.

In contrast, the interaction between the scapula and humerus, termed the "scapulohumeral rhythm," is widely accepted by orthopedic surgeons and helps in the understanding of joint movements. The term describes the movement of the scapula relative to the movement of the humerus through a certain range of motion. In shoulder abduction, the ratio of the scapulothoracic to glenohumeral movement is 1:2.[4]

We hypothesized that during wrist joint motion there is a "wrist rhythm" similar to the scapulohumeral rhythm. Therefore, we used a flat-panel detector to evaluate the ratio of the radiolunate (RL) and capitolunate (CL) joint motions during wrist joint motion by dynamic radiography.

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PATIENTS AND METHODS

Patients

The subjects were 20 healthy men (40 hands) without past trauma or any disorder in or near the wrists. Their age range was 22–49 years (mean, 29.3 years). Informed consent was obtained before the study commenced. This study was approved by the ethics committee of our hospital.

Imaging

A direct-conversion type of dynamic flat-panel detector (FPD; SonialVision Safire II; Shimadzu, Kyoto, Japan) and an X-ray tube (CIRCLEX J-type, 0.4/0.7 JG326D-265AT; Shimadzu, Kyoto, Japan) were used to obtain sequential images. For motion imaging, a 16-bit grayscale output was used. The matrix size was approximately 768×768 pixels, and the pixel size was 0.26×0.26 mm. To obtain clear lateral images of the wrist, the hand was placed in a grip position and the forearm was slightly supinated. A supportive device (Fig. 1) was used so that the metacarpophalangeal joints of the index finger and middle finger were perpendicular to the FPD. Dynamic imaging of the wrist joint during active exercise was performed for a total of ten seconds, five seconds from the maximum palmar flexion to the maximum dorsiflexion followed by five seconds from the maximum dorsiflexion to the maximum palmar flexion. The exposure conditions were a tube voltage of 65 kV, tube current of 250 mA, pulse width of 8.0 ms, source image distance of 1.5 m, and frame rate of 3.75 frames per second. In dynamic imaging, the exposure dose was approximately 0.77 mGy.

Image Analysis

Image-processing software (Image J v. 1.45; NIH, available at http://rsb.info.nih.gov/ij/) was used to perform image analysis. The following were analyzed: wrist angle, RL angle, and CL angle (Fig. 2). In this study, the wrist angle was defined as the angle between the line of the dorsal aspect of the radius (line A) and the line of the dorsal aspect of the third metacarpal bone (line B). The RL angle was defined as the angle between line A and the line perpendicular to the distal articulation of the lunate (line C). The CL angle was defined as the angle between lines B and C.

Fig. 1 A supportive device. To obtain clear lateral images of the wrist, the hand was placed in a grip position and the forearm was slightly supinated.

Fig. 2 X-ray images and measured angles; X: wrist angle, Y: RL angle, Z: CL angle.

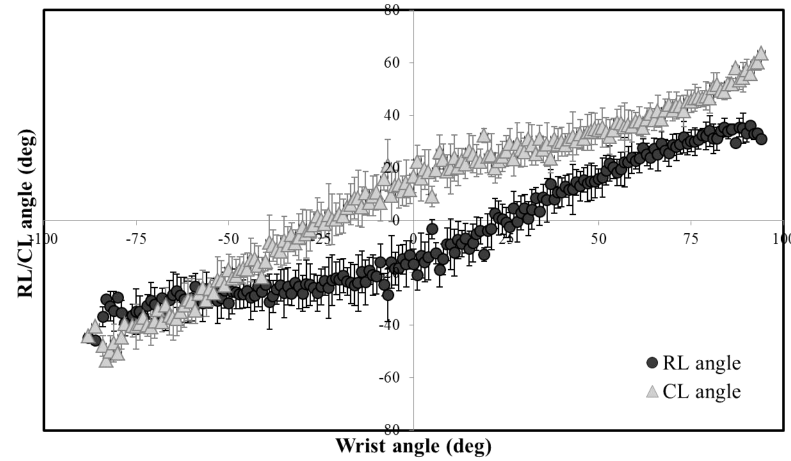

Fig. 3 Mean curves calculated from data of the 20 patients (40 hands). Mean values were calculated for the RL and CL angles at every one degree of the wrist angle.

The measurements taken from 40 wrists of the 20 patients were used to construct a graph with wrist angles on the x axis and the RL and CL angles on the y axis. On the graph, the dorsiflexion direction is "+" and the palmar flexion direction is "-". The mean RL and CL angles were calculated, and the average curve was plotted (Fig. 3). Next, the mean maximum palmar flexion and mean maximum dorsiflexion angles were calculated. The ratio was calculated from the slopes of the regression lines of the RL and CL angles.

RESULTS

The mean maximum palmar flexion angle was 65°, and the mean maximum dorsiflexion angle was 80°. For the interval between the neutral position and 65° palmar flexion, the regression line of the RL angle was $y = 0.188x - 18.96$ (coefficient of determination: $R^2 = 0.67$) and the regression line of the CL angle was $y = 0.814x + 18.42$ ($R^2 = 0.97$; Fig. 4). Thus, the ratio of the RL and CL angle motions during palmar flexion was 1:4.34. For the interval between the neutral position and 80° dorsiflexion, the regression line of the RL angle was $y = 0.647x - 16.43$ ($R^2 = 0.97$) and the regression line of the CL angle was $y = 0.354x + 16.88$ ($R^2 = 0.91$; Fig. 5). Thus, the ratio of the RL and CL angle motions during dorsiflexion was 1.83:1. Because the ratio differed depending on the intervals used in calculation, the ratios were examined for intervals from the neutral wrist position to the palmar flexion angle and to the dorsiflexion angle of 55°–85° at every five

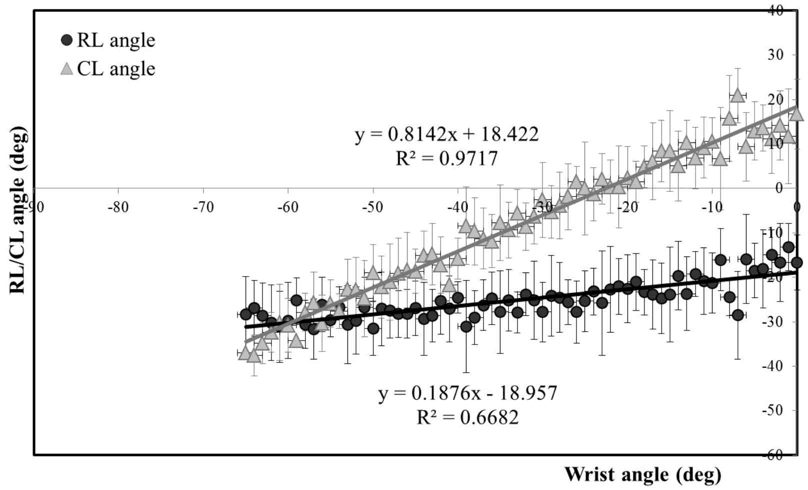

Fig. 4 Regression line from the neutral position to the mean palmar flexion angle of 65°.

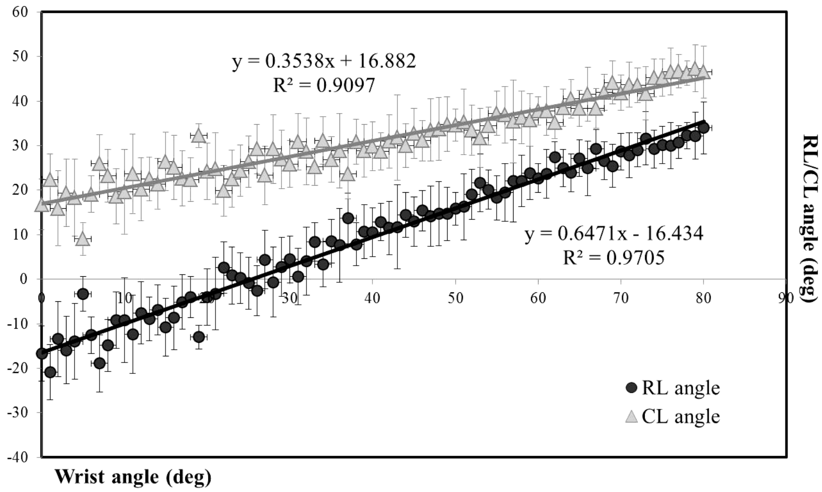

Fig. 5 Regression line from the neutral position to the mean dorsiflexion angle of 80°.

Table 1 Ratio of Regression Coefficients for Palmar Flexion and Dorsiflexion.

	The Regression Coefficient		
Palmar Flexion Angle (°)	RL Angle	CL Angle	Ratio
0–55	0.221	0.785	3.55
0–60	0.203	0.800	3.94
0–65	0.188	0.814	4.34
0–70	0.192	0.809	4.21
	The Regression Coefficient		
Dorsiflexion Angle (°)	**RL Angle**	**CL Angle**	**Ratio**
0–70	0.671	0.330	2.03
0–75	0.659	0.342	1.93
0–80	0.647	0.354	1.83
0–85	0.631	0.370	1.71

degrees (Table 1). However, there were no major differences in the ratios.

The above findings indicated that the ratio of the RL and CL angle motions was approximately 1:4 during palmar flexion and approximately 2:1 during dorsiflexion.

DISCUSSION

Most reports on wrist joint movement have examined the "contribution ratios" of the radiocarpal and midcarpal joints.[5,6] However, only the ratios of angles of each joint at certain points (maximum palmar flexion and maximum dorsiflexion) are used to find the contribution ratios. In contrast, the "scapulohumeral rhythm" is a well-known concept related to the movements of the shoulder joints and is based on the ratio of joint movements in a range of motion over a certain interval instead of at a certain point. Inman *et al.* first reported that in shoulder abduction, the ratio was 1:2 for the scapulothoracic to glenohumeral movement.[4] At present, many reports are still published about the scapulohumeral rhythm. However, till date, there have been no reports in which a method similar to the "scapulohumeral rhythm" was used to evaluate wrist joints. Although the results obtained were different from ours, Wolfe *et al.* published the only report on the ratio of the radiocarpal joint to midcarpal joint movements. They concluded that motion occurred equally at the midcarpal and radiocarpal joints.[7] However, the study comprised only five subjects, and analysis of the wrist angle was performed at 10° intervals.

The present study used the report on scapulohumeral rhythm by Braman *et al.* as a reference and calculated the "wrist rhythm". The regression lines were calculated from the data obtained at certain angle intervals, and the ratio of their slopes were calculated. In this study, the objective was to obtain the ratio of the joint movements in the general framework of wrist palmar flexion and dorsiflexion. Thus, the point of reference was set at a neutral wrist position of 0°. At both ends, the limits were defined as the mean maximum palmar flexion angle and the mean maximum dorsiflexion angle. The ratio of regression line slopes was examined for the angles around maximum angles, but there were no differences in the ratios.

These results indicate that there was no problem regarding the setting of intervals.

As mentioned earlier, there have been studies on how the scapulohumeral rhythm changes under various conditions. It is interesting that there is a large variability in the scapulohumeral rhythm values calculated in these reports.[8–12] For example, the rhythm had a wide range from 1.35:1 to 7.9:1 in the reports of Yoshizaki *et al.*[12] There is an opinion that the report of Inman *et al.*[4] oversimplified the results. However, the report has been frequently cited and used as the basis of many studies because they described the movements of the scapulothoracic joint and the glenohumeral joint in a simple and easy-to-understand manner. Therefore, we decided to evaluate the "rhythm" of the wrist joint.

In recent years, there have been an increasing number of reports on dynamic imaging using dynamic FPD.[13,14] Motion analysis is easy, convenient, and is becoming more common. The present study used FPD with high sensitivity as the imaging technique. Thus, images were obtained at low-exposure doses and without distortion. This type of imaging can be performed more easily and conveniently than magnetic resonance or computed tomography imaging. In the present study, the exposure dose for the 10 s imaging time was approximately 3.5 times the dose for lateral plain radiography of the wrist joint. The exposure dose has decreased with advances in technology. Thus, dynamic imaging is a diagnostic method whose benefits should be re-examined. This method can be applied to pre- and postoperative evaluations and to rehabilitation.

The present study examined "wrist rhythm", which can help in the understanding and education of complex movements of the wrist joint. We hope that the method in this study will be applied to detection of abnormal wrist movements pre- or post-operatively. In the future, we would like to examine the changes in the "wrist rhythm" for various conditions and diseases.

CONCLUSION

We evaluated the ratio of motion of the radiolunate and capitolunate joints during wrist joint motion. There was a "rhythm", which we hypothesized to be similar to the scapulohumeral rhythm. In palmar flexion, the ratio of the radiolunate and capitolunate motions was approximately 1:4, and in dorsal flexion, the ratio was approximately 2:1. We would like to propose these results as characteristic of "wrist rhythm".

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